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Report to
THE FEDERAL HOUSING
ADMINISTRATION

A STUDY OF SERIAL DISTRIBUTION FOR SOIL ABSORPTION SYSTEMS

April 8, 1959

PUBLIC HEALTH SERVICE...ROBERT A. TAFT SANITARY ENGINEERING CENTER

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A Study of Serial Distribution

for

Soil Absorption Systems

by

Gerald M. Sullivan
Asst. Sanitary Engineer

James B. Coulter
Sr. Sanitary Engineer

Thomas W. Bendixen
Soil Scientist

Field Investigations by

W. F. Smith, Sr. Asst. Sanitary Engineer
A. J. Muhich, Asst. Sanitary Engineer

Random Sampling Experiment by

Harold A. Thomas, Jr.
Gordon McKay Professor of
Civil and Sanitary Engineering
Harvard University

Allan B. Edwards
Asst. Sanitary Engineer

April 8, 1959

PUBLIC HEALTH SERVICE
Robert A. Taft Sanitary Engineering Center
4676 Columbia Parkway
Cincinnati 26, Ohio

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CONCLUSIONS

1. The distribution box is an expensive and ineffective adjunct to a soil absorption system.
2. Fundamental physical, chemical and biological questions concerned with the intrinsic efficiency of the several possible schemes of distribution have not been resolved. However, in the light of the results of recent investigations, it is concluded that performance can be improved by a method of positive hydraulic control that brings effluent into contact with all of the design area in such a way that the full capacity of the entire system is used before failure can occur. This control can be obtained with serial distribution.
3. On sloping ground when there is a difference in the absorptive capacities of the several trenches, the efficiency of parallel distribution (even with perfect distribution) is inherently low compared with serial distribution.
4. Employment of serial distribution will result in a more economical installation that is easier to construct and inspect.
5. Absorption field designs for level and sloping topography utilizing the serial distribution principle are presented. These designs illustrate methods of obtaining the hydraulic control necessary to insure complete use of the absorption area provided (page 17).

ACKNOWLEDGMENTS

The study described in this report emanated directly from the project to determine if distribution boxes can be eliminated without inducing increased failure of disposal fields. Both this and the parent project were sponsored by the Federal Housing Administration and conducted by the Robert A. Taft Sanitary Engineering Center.

A board of consultants consisting of:

Professor P. H. McGauhey, Director
Sanitary Engineering Research Laboratory
Engineering Field Station
University of California
Richmond, California

Mr. Clarence S. Slater
Soil Scientist
Department of Agriculture
Agriculture Research Service
Beltsville, Maryland

Dr. Harold A. Thomas, Jr.
Gordon McKay Professor of
Civil and Sanitary Engineering
Harvard University
Cambridge, Massachusetts

assisted in planning the study and in the review of analysis and interpretation of results. Mr. J. R. Simpson, Chief Sanitary Engineer, and Mr. Bernard T. Craun, Sanitary Engineer, both of the Federal Housing Administration, participated in the meetings with the consultants and provided liaison with the F.H.A.

INTRODUCTION

The conclusion of the distribution box report (1) that "...distribution boxes can be eliminated..." immediately posed the problem of providing alternate methods of distributing effluent to the various segments of a soil absorption system. That study was not designed to determine if other methods of distribution are superior; however, the data collected during the study do allow a direct comparison between systems using distribution boxes and systems using a serial distribution principle. This report deals exclusively with a comparison of the performance and relative merits of serial distribution systems and distribution box systems.

Soil has been used as a medium for subsurface disposal of effluent from individual household septic tank systems for over 50 years. However, it is only within recent years that soil conditions which provide successful disposal have been studied. Even now little is known concerning the proper type of pretreatment of sewage or the most effective method of application of effluent necessary to obtain maximum efficiency of the system. Soil receiving treated sewage is subject to biological, physical, and chemical clogging. Little is known of the fundamentals involved, or of the features which should be designed into an absorption system to minimize or control clogging.

The "Manual of Septic Tank Practice"(2) is one of the most comprehensive sources of information available on this subject. However, the Manual was based on data available prior to 1954, and recent investigations have provided enough additional information to indicate that changes should be made. The Manual states that:

"A distribution box is considered essential for every absorption field system. The purpose of the box is to insure equal distribution of effluent to the several lines."

A radically different design, wherein the distribution box is eliminated and serial distribution is used, is now proposed as a result of studies reported herein.

Serial distribution in an absorption system is accomplished by the use of separate trenches connected in a series. All of the effluent is discharged to the first trench and an overflow line is arranged so that the trench is forced to pond to the full depth of the gravel before liquid flows into the second trench. The overflow line lies below the surface of the ground on undisturbed earth, and is arranged to give relief before liquid seeps to the surface. Succeeding trenches come into play similarly in serial sequence so that the total absorption area of the entire system is utilized before final failure can occur.

Even though the record is meager, serial type systems have been more widely used than is generally realized. These serial types have been encountered or their use has been reported in Alabama, Mississippi, Missouri, New York, North Carolina, Oklahoma, and Tennessee. In the course of seminars and training sessions sponsored by the Public Health Service during the past decade, comments on the use of serial arrangements have been made by local authorities and installers attending the meetings.

Serial arrangements take different names in different localities. An early instance coming to the attention of Center personnel concerned the use of "Step Down" systems in Mississippi. As a result of correspondence with Dr. Felix J. Underwood of the Mississippi State Health

Department, a series of "bench type" experiments were made on selected soil cores. The favorable results of these unreported experiments indicated the need for the distribution box study. The "Land Block" systems of St. Louis County, Missouri, were investigated and the results are presented in the following section.

Kiker(3) shows an illustration of the use of "drop boxes" from the New York State recommendations. Other state bulletins illustrate "drop box" arrangements without commenting on the use of serial distribution.

Quenelle(4) has developed, studied, and reported on the use of "S" type systems in Alabama which utilize a serial distribution principle. Long single trenches which in effect work on the serial principle are used in a number of states.

ADVANTAGES OF SERIAL DISTRIBUTION

Improved Hydraulic Control. Many times during the current studies the need has been observed for positive hydraulic control necessary to bring liquid into contact with the entire soil absorption area so that the total capacity of the system is developed. It has also been observed that this control is not always achieved with the distribution box, especially on sloping ground.

With imperfect division of flow in a system of parallel trenches installed at different elevations, one trench is almost certain to be overloaded and eventually becomes surcharged. If the difference in elevation between the surcharged trench and the distribution box or other flow splitting device is such that the trench continues to

receive more than it can absorb, surface seepage and local failure will occur before the full capacity of the system can be utilized.

Failure, as used herein, is defined as the inability of the system to absorb a full day's flow of sewage within a 24 hour period, and is evidenced by seepage to ground surface or sluggish draining of household plumbing fixtures.

If an approximately equal division of flow is to be achieved, distribution boxes must be constructed and installed with far more precision and attention to detail than in present practice. Furthermore, to obtain an equal split of flow during the 10 to 20 year life of the system, the box must be maintained and adjusted frequently.

However, there is a serious question of whether the additional expense to attain perfect distribution would be justified in terms of improved performance in view of the inherent difference in absorptive capacities of different trenches in a given system.

Compensation for Variability in Absorptive Capacity of Trenches. The variability of soils, even in the limited area of an individual disposal field, makes the desirability of uniform distribution doubtful. Many factors, alone or in combination, may lead to nonuniform absorptive capacity of the several trenches. Varying chemical and physical characteristics of the soil, construction damage such as soil interface smearing or excessive compaction, poor surface drainage, influence of plant growth, and variation in depth of the trenches are some of the factors involved.

To illustrate the effects on absorption system performance of varying absorptive capacities between trenches and imperfect division of flow by the distribution box, the following results of a random sampling experiment* are given. The average period of successful operation for 99 hypothetical soil absorption systems, whose overall capacity and total loading were identical, was computed for 3 different combinations: (a) imperfect distribution of flow in a nonuniform soil, (b) perfect distribution of flow in a nonuniform soil, (c) imperfect distribution of flow in uniform soil. Systems in situation (a), which is the usual case, have an average life of 8.7 years. Situation (b) shows an average life of 10.1 years, and situation (c) shows an average life of 11.7 years. The conditions of total loading and overall system capacity were such that if perfect distribution as well as uniform soil existed, the life of each of these systems could have been 20 years. It can be seen that the improvement in system performance achieved by perfecting the distribution box is small, and the average life of systems designed to operate on the principle of parallel distribution is considerably less than the maximum. Serial distribution, not being subject to the restrictions imposed by situations (a), (b) and (c) above, would achieve the maximum possible life of 20 years under the same conditions of loading and overall system capacity.

Thus, if the absorptive capacities of the trenches are not equal, the principle of equal flow is immediately fallacious. On sloping ground serial distribution minimizes the dependence on individual

*The calculations for this experiment are given in the appendix.

trench absorption rates because each trench absorbs effluent to its ultimate capacity. With equal distribution on sloping ground, the life of the system is limited by the capacity of the weakest trench; with serial distribution, full use is made of every trench.

ANALYSIS OF DATA

In St. Louis County, Missouri, a method of serial distribution known as the "land block" system was used for several years during the early 1950's. During the distribution box study 164 of the systems were encountered. These data were re-examined and 70 of the systems were determined to be true serial distribution systems. The performance of these 70 was compared with 171 distribution box systems that were installed during the same period under similar conditions.

Validity of Comparison. Many factors other than the method of distributing the effluent affect the performance of septic tank systems. A bias produced by any one, or a combination of these factors favoring one system over the other, could produce misleading results. Since the data being analyzed were all collected within the jurisdiction of a single local health department, the chance of bias in such factors as age, soil, area, design, control, construction and climatic conditions was reduced. No peculiarities were detected which might render conclusions valid only for the St. Louis area.

A direct comparison of factors previously demonstrated[1] to have a significant bearing on performance is presented in Table 1. A distribution of both types of systems by slope is shown in Table 2.

Table 1

Significant Factors Compared

Significant Factors	St. Louis Distribution Box Systems	St. Louis Land Block Systems
Average Age of Systems	1.4 yrs.	3.2 yrs.
Average Loading, Persons/home	4.0 pers.	3.7 pers.
Average Absorption Area/person	123 ft^2	123 ft^2
Percent of systems in cut or fill	4	10
Percent of systems in $\geq$4% slope	6	47
Percent of systems in poor* soil	13	53
Percent of systems in fair* soil	81	41
Percent of systems in good* soil	6	6
Percent of systems having food waste grinders	20	21

*As based on percolation tests.

Table 2

Distribution by Slope

% Slope	Distribution Box		Land Block	
	No. of Systems	% of Systems	No. of Systems	% of Systems
0	72	42	7	10
1	56	33	9	13
2	27	16	17	24
3	4	2	4	6
4	1	1	0	0
5	8	5	18	26
6 - 10	1	1	7	10
Over 10	2	1	8	11
Total	171		70	

Even though an effort was made to select systems where conditions would allow an unbiased comparison of performance, the data show a bias in favor of distribution box systems. They are on the average younger, installed in better soil, and on flatter ground. Also, fewer of the distribution box systems were in cut or fill ground. No bias is apparent in loading or area provided. On the basis of factors in Table 1, more successful operation of distribution box systems should be expected.

Direct Comparison of Failure Rates. In Tables 3 and 4 the performance of the two types of systems is compared. Taking into account alteration to topography and slope of the ground, a consistently lower failure rate is indicated for land block systems and particularly on the steeper sloping ground.

While the data are insufficient to demonstrate a statistically significant difference, a lower failure rate is indicated in land block systems, despite the fact that distribution boxes should have been superior because of being clearly favored by age, soil, and slope.

Table 3

Performance of Distribution Box and Land Block Systems

Alteration to Topography	Distribution Box				Land Block			
	0 - 4% Slope		Over 4% Slope		0 - 4% Slope		Over 4% Slope	
	Total	Failures	Total	Failures	Total	Failures	Total	Failures
None	155	18	9	4	35	3	28	6
Cut or Fill	5	1	2	2	2	0	5	2
Totals	160	19	11	6	37	3	33	8

Table 4

Percent Failing

Alteration to Topography	Distribution Box		Land Block	
	0 - 4% Slope	Over 4% Slope	0 - 4% Slope	Over 4% Slope
None	12	44	9	21
Cut or Fill	20	100	0	40
Total Systems	12	55	8	24

Comparison of Survival Curves. In the foregoing direct comparison of failure rates, the time that systems had been in service ranged over a period of several years. To allow a comparison of the two types of systems in groups of equal age, and to show the cumulative effect of early failures, survival type life tables and curves were prepared. In order to extend the age range and to establish the best possible base for distribution box systems, a survival curve for the combined Alexandria, Louisiana and St. Louis, Missouri data was calculated. This curve is based on 440 cases. Statistics for this sample on other factors that may affect system performance are given in Table 5. A comparison of this table with Column 3 of Table 1 again shows a sample bias in favor of the distribution box systems.

Table 5

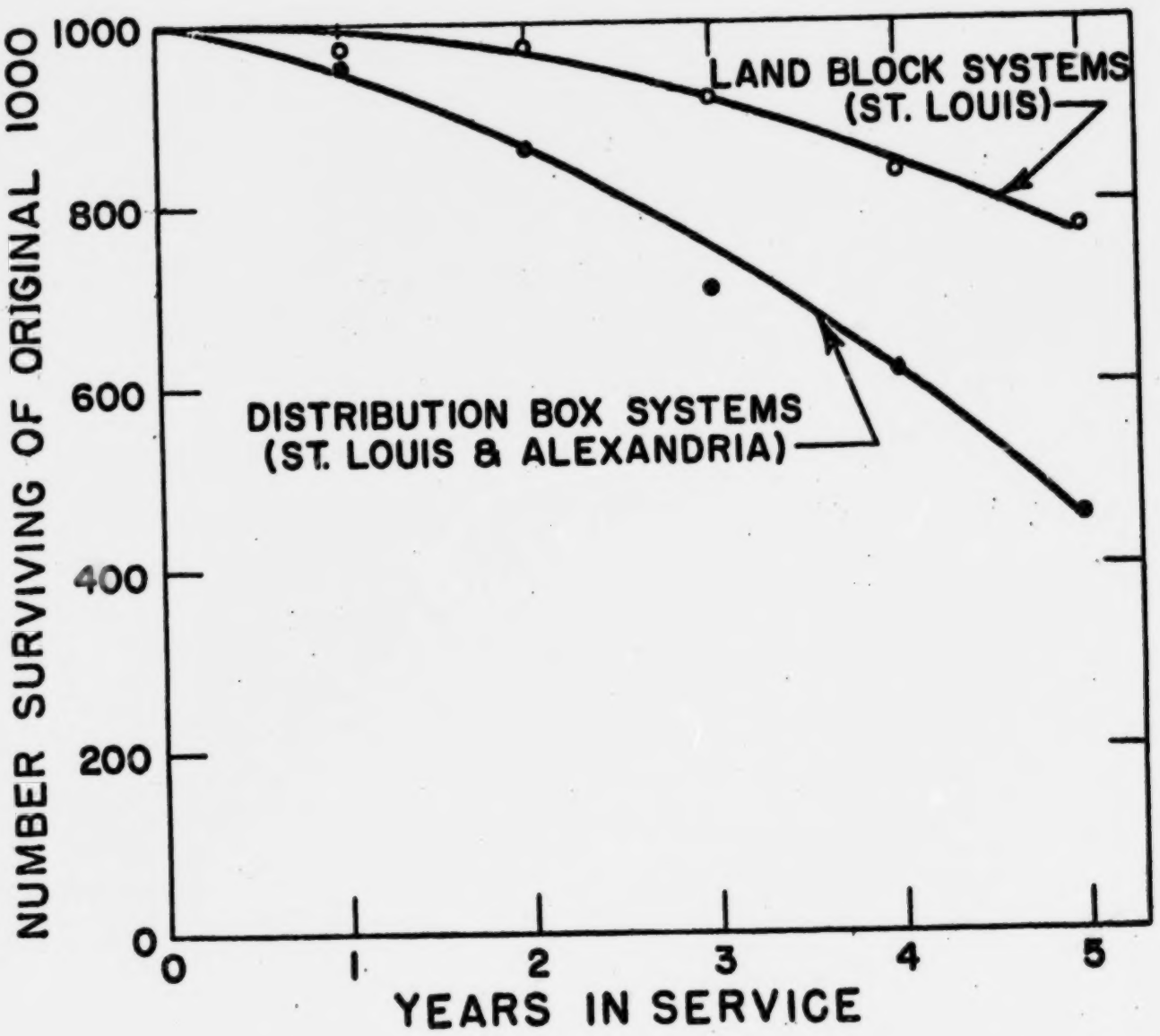
Significant Factors of Distribution Box Systems
St. Louis and Alexandria Combined

Average age of systems	1.9 years
Average loading, persons/home	4.1 persons
Average absorption area/person	145 ft^2
Percent of systems in cut or fill	6
Percent of systems in > 4% slope	6
Percent of systems in poor* soil	11
Percent of systems in fair* soil	35
Percent of systems in good* soil	54
Percent of systems having food waste grinders	9

*As based on percolation tests.

The survival curves are shown in Figure 1 and the calculations for arriving at the curves are given in Tables 7 and 8.

While it cannot be claimed that the difference in the curves has a high level of statistical significance, it is evident that the early experience with serial distribution systems was better than that with the distribution box systems.



SURVIVAL CURVES

FIGURE 1

Table 6

Distribution Box Systems, St. Louis and Alexandria
Survival Curve Calculations

Age Interval	No. of Installations	No. of Systems Failing During Age Interval				
		0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9
0-0.9	61	5				
1.0-1.9	216	12	33			
2.0-2.9	115	3	1	29		
3.0-3.9	16				6	
4.0-4.9	32	1				8
Total	440	21	34	29	6	8

Age of System	No. Reaching Age Interval	No. Failed	q_x	l_x	d_x
0-0.9	440	21	0.048	1000	48
1.0-1.9	363	34	0.094	952	90
2.0-2.9	158	29	0.183	862	157
3.0-3.9	47	6	0.127	705	90
4.0-4.9	31	8	0.258	615	159
5.0-5.9				454	

Table 7

Land Block Systems, St. Louis
Survival Curve Calculations

Age Interval	No. of Installations	No. of Systems Failing During Age Interval				
		0-0.9	1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9
0-0.9	0					
1.0-1.9	2					
2.0-2.9	18	1		3		
3.0-3.9	42	1		1	5	
4.0-4.9	13					1
Total	75	2	0	4	5	1

Age of System	No. Reaching Age Interval	No. Failed	q_x	l_x	d_x
0-0.9	75	2	0.027	1000	27
1.0-1.9	73	0	0	973	0
2.0-2.9	71	4	0.056	973	54
3.0-3.9	53	5	0.094	919	86
4.0-4.9	13	1	0.077	833	64
5.0-5.9				769	

DISCUSSION

The data together with practical considerations indicate that a serial method of distribution will result in better performance than that obtained with a more conventional design. A previous report(1) conclusively demonstrated that a distribution box is an ineffective accessory to the disposal system. Its use does not reduce failure rates nor increase life expectancies. On the other hand, there is a definite indication that serial distribution tends to reduce failure rates and to increase life expectancies. Although the data are insufficient to demonstrate statistically the superiority of serial distribution systems over distribution box systems, the fact that the former were more successful under more adverse conditions of soil, slope, and alteration to topography lends strong argument to their preference.

Advantages, such as forced use of the total absorption area available and the automatic adjustment to soil variability, strongly favor serial distribution systems. Use of serial distribution will also result in a substantial reduction of installation costs. The elimination of the distribution box will reduce first cost approximately $15 to $30 per system, depending on the amount of tight-joint pipe eliminated. Serial distribution is also less prone to construction error. Furthermore, because it may be of a simpler design, it is more amenable to administrative control.

Even though some theoretical questions remain unresolved, it is apparent that the present level of performance of absorption systems can be substantially improved by a serial method of distribution.

APPLICATION OF RESULTS

The provisions regarding the need for distribution boxes in soil absorption systems for private residences are based on the premise that uniform distribution of effluent over the total designed absorption area is necessary. Distribution boxes have been employed in an effort to obtain uniform or parallel distribution.

Recent studies sponsored by the Federal Housing Administration have demonstrated that various arrangements in the tile field, including the distribution box, do not achieve uniform distribution. Furthermore, it has never been established that equal distribution has any intrinsic advantages as opposed to some arrangement of serial distribution. Serial distribution is achieved by arranging individual trenches of the absorption system so that each trench is forced to pond to the full depth of the gravel fill before liquid flows into the succeeding trench. In this manner, the total absorption area of the entire system is utilized before ultimate failure can occur.

Serial distribution has the following advantages:

1. Serial distribution minimizes the importance of variable absorption rates by forcing each trench to absorb effluent until its ultimate capacity is utilized. The variability of soils even in the small area of an individual absorption field raises doubt of the desirability of uniform distribution. Any one or a combination of factors may lead to nonuniform absorptive capacity of the several trenches in a system.

Varying physical and chemical characteristics of the soil, construction damage such as soil interface smearing or excessive compaction, poor surface drainage, and variation in depth of trenches are some of the factors involved.

2. Serial distribution causes each trench in the absorption system to be used to full capacity before failure occurs. Serial distribution has a distinct advantage on sloping terrain. With imperfect division of flow in a parallel system, one trench could become overloaded, resulting in a surcharged condition. If the slope of the ground and elevation of the distribution box were such that a surcharged trench continued to receive more effluent than it could absorb, local failure would occur before the full capacity of the system was utilized.
3. The cost of the distribution box is eliminated in serial distribution. Also, long runs of closed pipe connecting the box to each trench are unnecessary.

Recommended Absorption Field Design.

A. On level ground (i.e. where ground in the area utilized for the absorption field does not exceed a maximum fall of six inches) any method of distribution is acceptable if:

1. The system is designed so that an overloaded trench can drain back to other trenches before effluent breaks to the ground surface.
2. Trenches have a minimum of 12 inches of cover.

3. The bottom of the trenches and the open-joint tile distribution lines have a level grade.
4. Other construction features of the disposal field are the same as recommended in the Manual.

A satisfactory level ground layout is shown in Figure 2.

B. Serial distribution may be used in all situations and is preferred where maximum fall of the ground surface above the disposal field exceeds 6 inches.

In serial distribution, each adjacent trench (or pair of trenches) is connected to the next by a closed pipe line laid on an undisturbed section of ground. The arrangement is such that all effluent is discharged to the first trench until it is filled. Excess liquid is then carried by means of a closed line to the next trench. In that manner, each portion of the subsurface system is used in succession. When serial distribution is used, the following design and construction procedures should be followed:

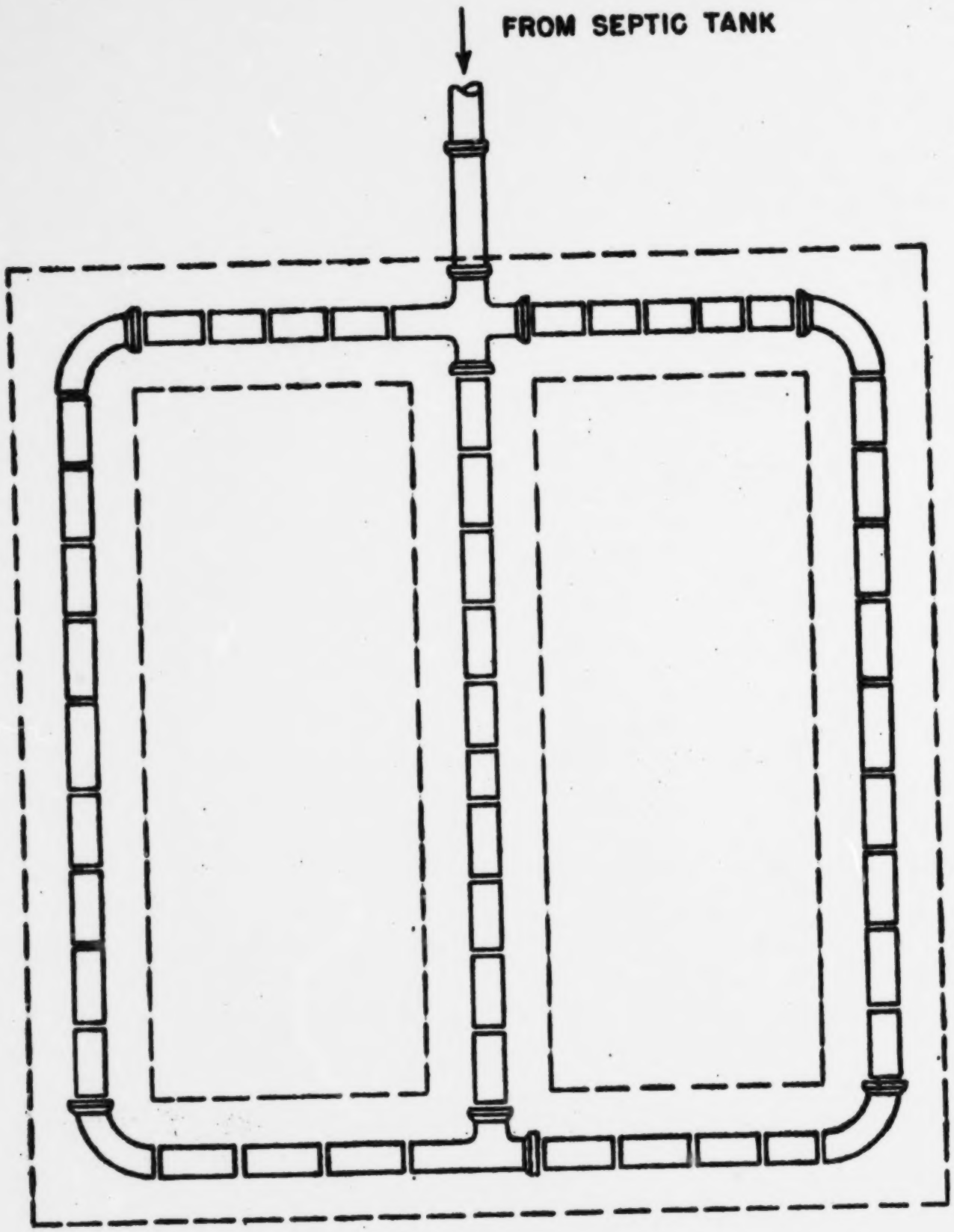
1. The amount of absorption area required shall be the same as shown in Table 1, Page 6, of the "Manual of Septic Tank Practice."
2. The bottom of the trenches and the open-joint tile distribution lines should have a level grade.
3. There should be a minimum of 12 inches of ground cover over the gravel fill.

4. The absorption trenches should follow approximately the ground surface contours so that variations in trench depth will be minimized.
5. The width of a serial distribution trench should not exceed 3 feet.
6. There should be a minimum of 6 feet of undisturbed earth between adjacent trenches, and between the septic tank and the nearest trench.
7. Adjacent trenches may be connected with a relief line or a drop box arrangement (Figures 3 and 4) in such a manner that each trench is completely filled with sewage to the full depth of the gravel before effluent flows to succeeding trenches. The sketches shown do not preclude the use of other arrangements to provide serial distribution.
   a. Trench connecting lines should be 4-inch tight-joint sewers with direct connections to the distribution tiles in adjacent trenches or to a drop box arrangement.
   b. Care must be exercised in constructing relief lines to insure an undisturbed block of earth between trenches. The trench for the relief pipe, where it connects with the preceding absorption trench, shall be dug no deeper than the top of the soil gravel interface. The relief line should rest on undisturbed earth and backfill should be carefully tamped.

c. The influent and effluent relief lines in each individual trench should be as far from each other as practicable in order to prevent short-circuiting.

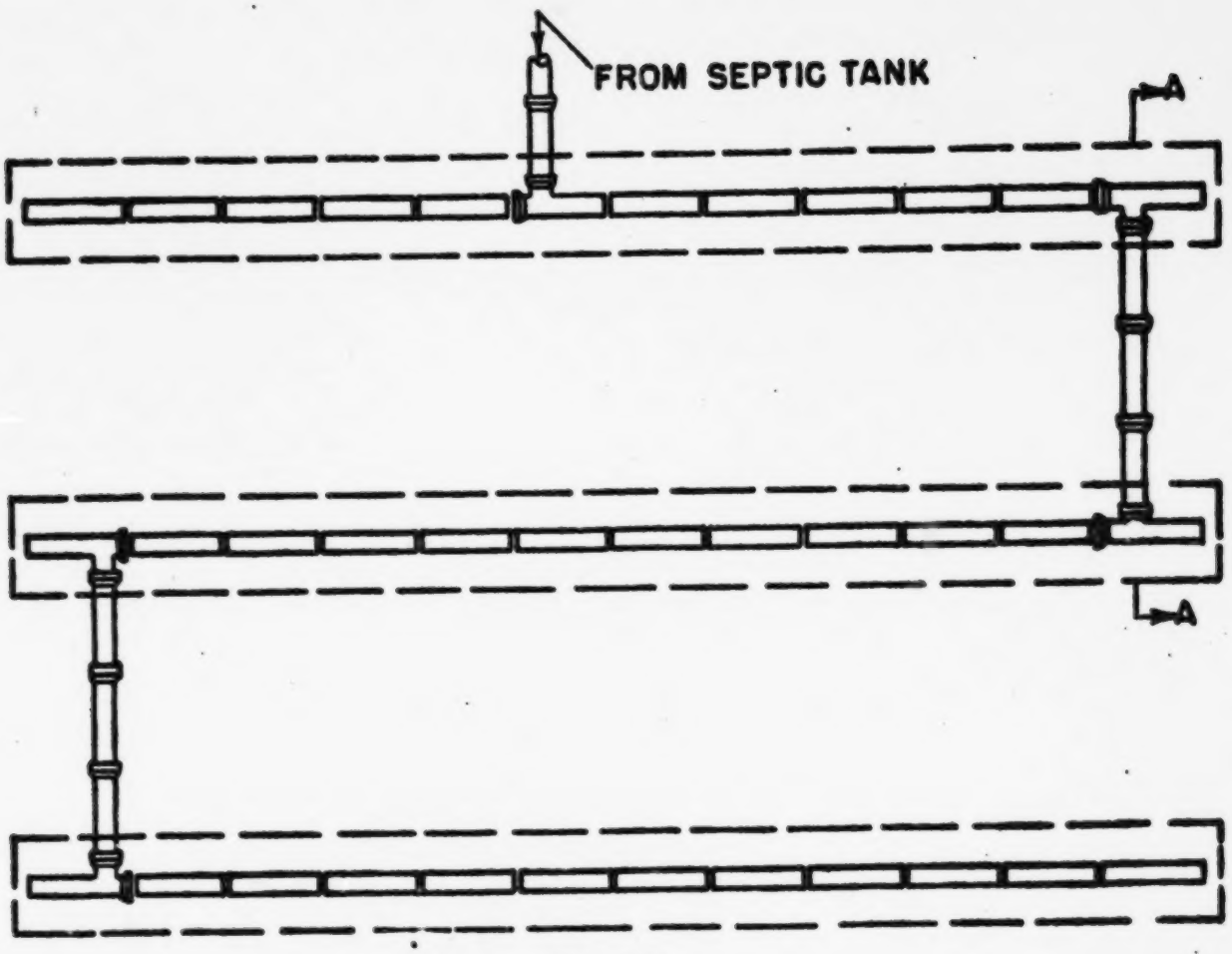
8. Overflow to the first relief line should be at least 4 inches lower than the septic tank outlet.

9. All other construction features of the disposal field are the same as recommended in the Manual.

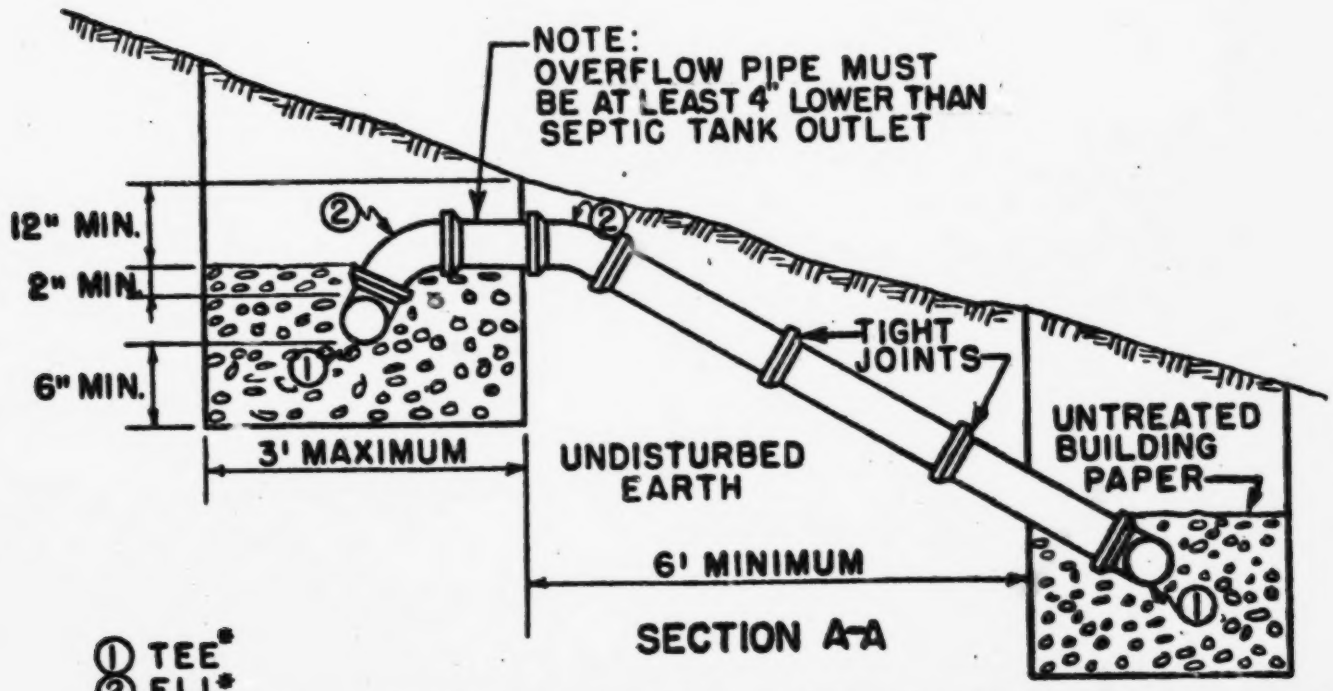


A DISTRIBUTION ARRANGEMENT
FOR LEVEL GROUND

FIGURE 2

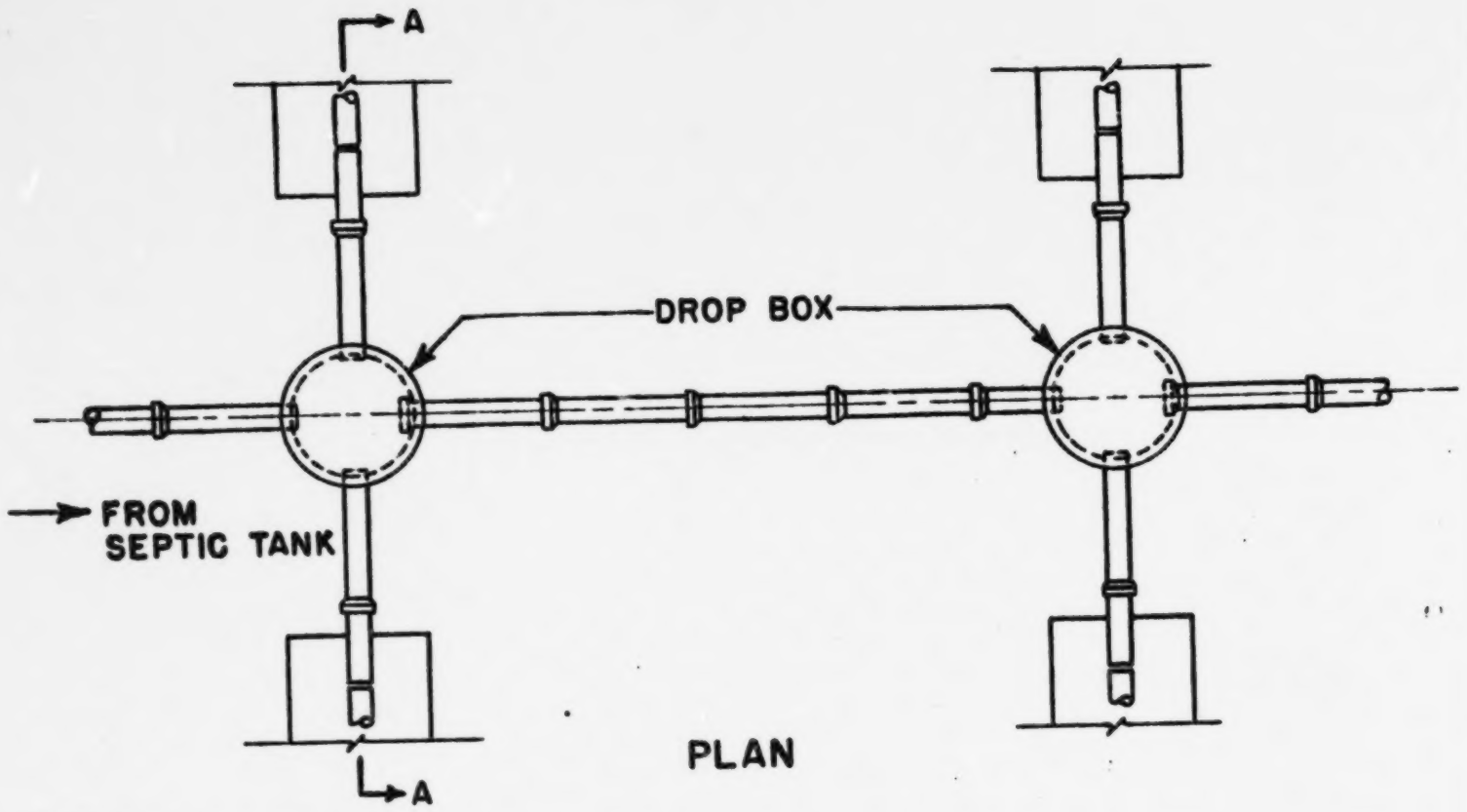


PLAN



A RELIEF LINE ARRANGEMENT FOR SERIAL DISTRIBUTION

FIGURE 3



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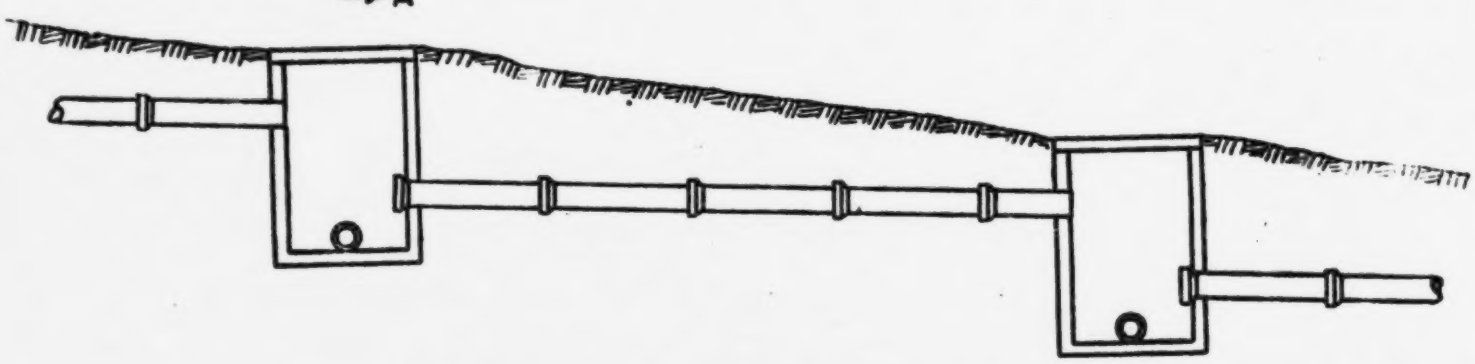

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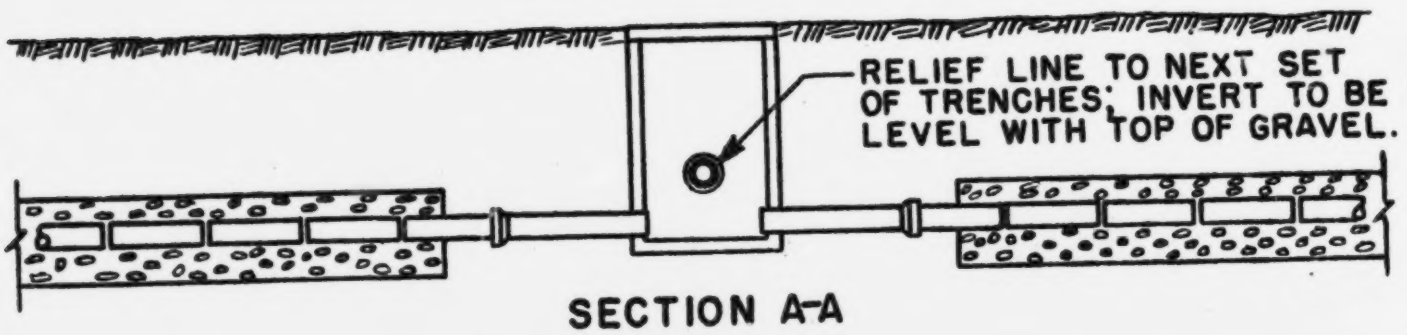


SECTION A-A

A DROP BOX ARRANGEMENT FOR SERIAL DISTRIBUTION

(AFTER N.Y. STATE DEPT. OF HEALTH BULLETIN NO. 1, MODIFIED - REF. #5)

FIGURE 4

References

(1) J. B. Coulter and T. W. Bendixen, "Final Report to the Federal Housing Administration on the Study to Determine if Distribution Boxes can be Eliminated Without Inducing Increased Failure of Disposal Fields," Public Health Service, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio (1958)

(2) U. S. Public Health Service, "Manual of Septic Tank Practice," Public Health Service Publication #526, U. S. Government Printing Office, Washington, D. C. (1957)

(3) J. E. Kiker, Jr., "Subsurface Sewage Disposal," University of Florida, Gainesville, Florida (1948)

(4) O. G. Quenelle, "Studies on Small Sewage Treatment Systems," Bureau of Sanitation, State Department of Public Health, Montgomery, Alabama (1957-58)

(5) New York State Department of Health, Albany, N. Y., "Rules and Regulations for the Preparation and Submission of Plans for Systems of Sewerage and Sewage and Waste Disposal," Bulletin No. 1 (1947)

APPENDIX

A Random Sampling Experiment Considering the Effects on Soil Absorption System Performance of (1) Imperfect Division of Flow by the Distribution Box and (2) Nonuniform Soil Within the Absorption Field

by

Harold A. Thomas
Consultant

Allan B. Edwards
Asst. Sanitary Engineer

When a soil absorption system is designed to operate on the principle of parallel distribution, two assumptions are intrinsic. The first is that the flow of liquid can be equally split by such a device as a distribution box, and secondly, all of the absorption trenches are identical as far as their ultimate capacity to absorb liquid is concerned. However, it is known that the distribution box generally creates an imperfect division of flow, and as well, the ultimate absorptive capacity (the maximum amount of liquid that can be absorbed before failure) of each trench is different.* The effect of these conditions on the overall performance of soil absorption systems designed to operate by parallel distribution can be evaluated by a statistical technique involving the use of random numbers.**

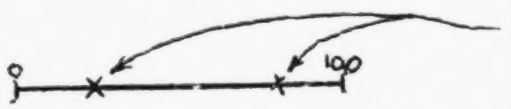
In general, the technique involves creating a group of hypothetical soil absorption systems which are identical with respect to total loading and total capacity and then imposing conditions of

* "Final Report ~~to the~~ FHA on the Study to Determine if Distribution Boxes can be Eliminated Without Inducing Increased Failure of Disposal Fields," and "Serial Distribution for Soil Absorption Systems."

** The fundamental theorems upon which this technique is based are given in W. A. Whitworth's book (1901, 5th Edition) Choice and Chance in the chapter on "Expectation of Parts."

imperfect distribution and nonuniform soil which are synthetically generated for each system by the use of random numbers. In all, there are four possible combinations of these conditions to consider: (1) perfect distribution in uniform soil which, of course, is the assumed theoretical combination of conditions, (2) imperfect distribution in nonuniform soil, which is the usual combination, (3) perfect distribution in nonuniform soil, and (4) imperfect distribution in uniform soil. Finally, the period of successful operation or life of each system is computed for each combination of conditions. An evaluation of these combinations of operating conditions is made by comparing the average life of the systems as well as the survival curves.

In order to theoretically create these combinations, with the exception of (1), it is necessary to statistically make random allocations of the total load and capacity among the trenches of the system. For example, if the system has 3 trenches, this allocation is made by creating a restrained rectangular distribution by choosing two numbers from a random number table which ranges from 00 to 99, and letting these two numbers locate two points on a percentage scale which represents total loading or capacity.



The percentage of the total load or capacity to be allocated to the first trench is merely the percentage represented by the smaller random number, the second trench receives the percentage of the total load or capacity denoted by the difference between the random numbers,

and the third trench receives the percentage of the total load or capacity represented by the difference between 100 and the larger of the two random numbers. The creation of combination (2) requires the selection of two pairs of random numbers: one pair to compute loading variation, and the other to compute absorptive capacity variation. Combinations (3) and (4) are obtained by using the appropriate values from (1) and (2).

Before beginning the computation, checks are made to insure a reasonable correspondence between the hypothetical group of systems and those which would exist in actual practice. One such check involves the values of total loading and soil absorptive capacity to be used; average or typical values would give the most reasonable results. Another check involves the coefficients of variation* for individual trench loading and capacity; these coefficients should be the same for the hypothetical and actual systems. In other words, variation of loading and capacity between trenches should be the same for these hypothetical systems and actual or real systems.

Extensive field surveys indicate that a typical soil absorption system serves 4 people. In an average soil, a three-trench absorption system has approximately 400 square feet of trench bottom area. Further findings indicate it is not unreasonable to expect malfunctions of the distribution box to cause a coefficient of variation for individual trench loading of 70 percent. Similarly, these field investigations indicate a value of 50 percent is reasonable for the coefficient of variation for individual trench absorptive capacities on a single lot.

*The ratio of the standard deviation to the mean.

If a group of hypothetical absorption systems consisting of 3 trenches with varying load and capacity is created by the random sampling method previously suggested, a coefficient of variation of 70 percent for both loading and capacity will be obtained. This figure was determined by computing the coefficient of variation for all possible values of the restrained rectangular distribution which the method produces. Thus, the procedure as outlined is satisfactory for allocating the total load, but some revisions will have to be made in order to achieve the desired coefficient of 50 percent for absorptive capacity. One method of achieving the desired coefficient of variation involves considering the total capacity as being made up of variable and fixed parts for computation purposes. The fixed part is equally divided among the 3 trenches, and only the variable part is allocated among them by means of random numbers. Thus each trench has a certain minimum capacity which will be unaffected by the allocation procedure. To obtain the desired coefficient of variation, simple proportions can be used; variable capacity is to total capacity as the desired coefficient is to the actual coefficient.

The actual computation is best illustrated by a sample computation. Using the average values for load and area given earlier (P = 4 persons and A = 400 square feet), and making the assumption that this system is located in a region where general experience indicates that one square foot of area can be expected to dispose of septic tank effluent for one person for 0.2 years, the ultimate absorptive capacity for this system is $C = AL = 400 \times .2 = 80$ person-years.

Combination (1) is satisfied, if each trench of a 3 trench system has a capacity of $\frac{80}{3} = 26.7$ person-years and receives the load from $\frac{4}{3} = 1.33$ persons. In this combination, the theoretical maximum life for the system is realized because the life of each trench is the same, $t = \frac{26.7}{1.33} = 20$ years.

Before combination (2) can be satisfied, the total capacity will have to be split into fixed and variable parts in order to achieve the desired coefficient of variation of 50 percent.

$$\frac{\text{Variable Capacity}}{\text{Total Capacity}} = \frac{.5}{.7} \text{ or Variable Capacity} = 80 \times \frac{.5}{.7} = 57.2 \text{ person-years}$$

Thus 57.2 person-years are to be randomly allocated to the 3 trenches and (80 - 57.2) person-years are to be equally divided among the 3 trenches. The computation is then carried out as outlined.

If the random numbers representing loading are 81 and 88, the percentages of the total load going to individual trenches are $y_1 = 81$, $y_2 = (88 - 81) = 7$, and $y_3 = (100 - 88) = 12$. Multiplying each percentage by the total load of 4 persons gives the actual load on each trench: $P_1 = 3.24$, $P_2 = .28$, and $P_3 = .48$. If the second pair of random numbers is 97 and 24, the percentage of the variable capacity to be divided among the 3 trenches is computed in a similar manner: $y_1 = 24$, $y_2 = (97 - 24) = 73$, and $y_3 = (100 - 97) = 3$. The actual trench capacities would be:

$C_1 = (.24)\ (57.2) + 7.6 = 21.3$ person-years,

$C_2 = (.73)\ (57.2) + 7.6 = 49.3$ person-years, and

$C_3 = (.03)\ (57.2) + 7.6 = 9.4$ person-years.

The total capacity of the system is, of course,

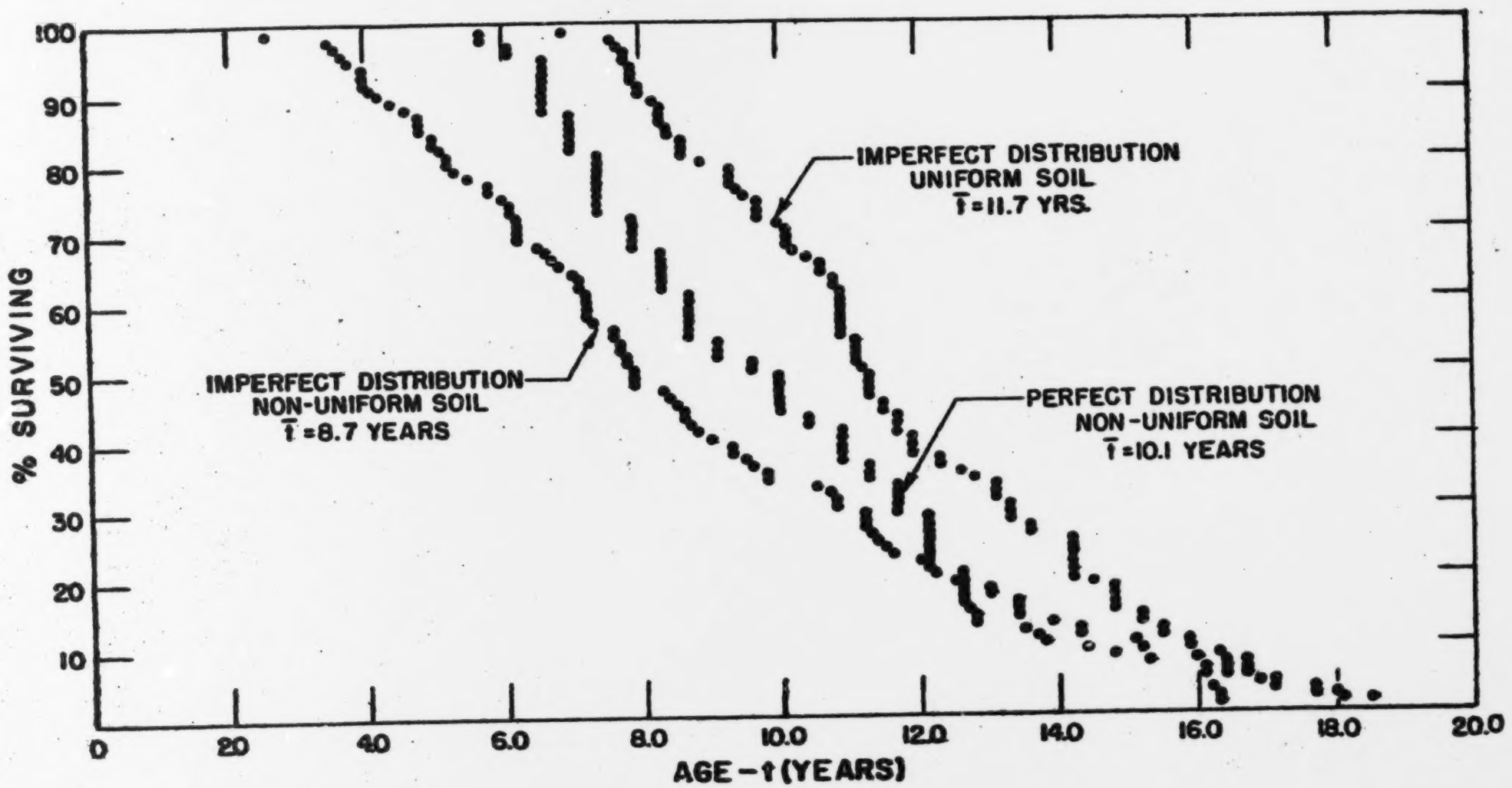
$C_T = C_1 + C_2 + C_3 = 80$ person-years.

The life of the system, using parallel distribution, is the minimum life of any of the 3 trenches. In the above example, the period of successful operation for each of the 3 trenches is as follows: $t_1 = \frac{21.3}{3.24} = 6.6$ years, $t_2 = \frac{49.3}{.28} = 176$ years, and $t_3 = \frac{9.4}{.48} = 19.4$ years; thus the system is a failure at 6.6 years when operating under combination (2).

If the distribution box were perfected, conditions for combination (3) would prevail. The load on each trench would equal 1.33 persons. The absorptive capacity of each trench would be unchanged so the life of each trench would be: $t_1 = \frac{21.3}{1.33} = 160$ years, $t_2 = \frac{49.3}{1.33} = 37.0$ years, and $t_3 = \frac{9.4}{1.33} = 7.0$ years. The system life is 7.0 years. Thus only a slight improvement in performance is realized by going to the additional expense of perfecting the distribution box. If by some means the variability in absorptive trench capacity could be eliminated, and the unperfected distribution box were used, combination (3) can be studied. The capacity of each trench would be 26.7 person-years and loading would be the same as in combination (2). The individual trench lives would be: $t_1 = \frac{26.7}{3.24} = 8.2$ years, $t_2 = \frac{26.7}{0.28} = 95.2$ years, and $t_3 = \frac{26.7}{0.48} = 55.6$ years. The system would fail at 8.2 years.

In all, these computations were repeated 99 times; thus, 99 systems were created for each combination. For each combination, the average life or period of successful operation was computed, and a survival curve was drawn. These results are shown on Figure 5. It can be seen that only a modest increase in average life is gained by

perfecting the distribution box (10.1 years as opposed to 8.7 years) or absorptive capacity (11.7 years as opposed to 8.7 years). Furthermore, the presence of one or both of the conditions of imperfect distribution and nonuniform soil reduces the life of a system designed to operate on the principle of parallel distribution to approximately one-half of its theoretical value.



SURVIVAL CURVES

FIGURE 5